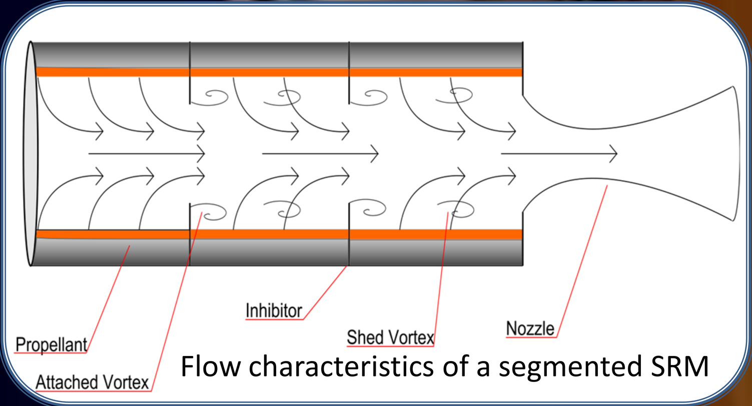
Relating Pressure Oscillations and Vortex Shedding in Solid Rocket Motors

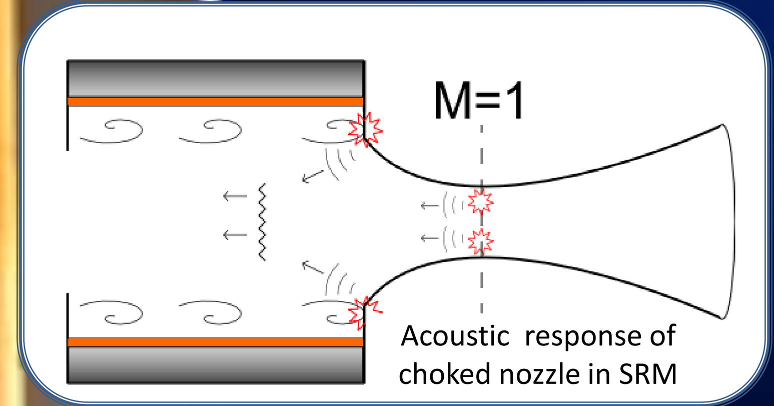
John Palmore: Cornell University
Elijah Stevens: University of Texas Arlington
Samantha Rawlins: California State University Los Angeles
Nick Zarbo: University of Maryland College Park
Principal Investigators: Philip Franklin ER52

Introduction

- Pressure oscillations in Solid Rocket Motors (SRMs) have the potential to damage hardware and passengers when the oscillations reach resonant frequencies
- Vortices shedding from combustion inhibitors are believed to be the source of these oscillations
- Our team designed and built a cold flow test chamber to simulate the inhibitor configurations and flow conditions of the SRMs in the Space Shuttle and the SLS launch vehicle



Flow characteristics of a segmented SRM



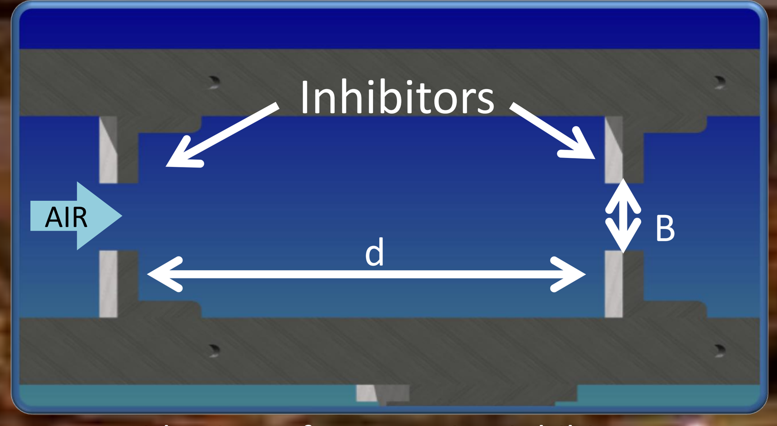
Acoustic response of choked nozzle in SRM

Previous Year's Design

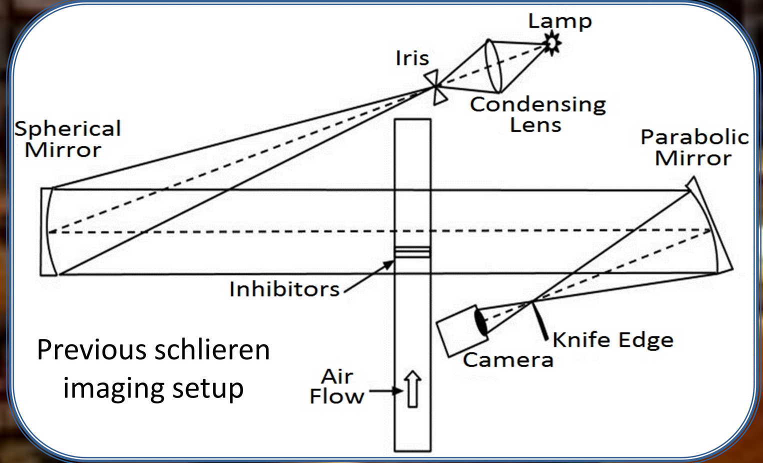
- Modeled test chamber in CAD
  - Included ports for pressure transducers and microphones
  - Flow conditions nearly match desired conditions
- Designed z-type schlieren visualization setup
- Uses 125psig building air supply

Desired and Theoretical Chamber Conditions

	Desired for chamber	Theoretical with chamber
Reynolds number	> $3x10^3$	10^4 - 10^5
Mach #	0.02 - 0.2	0 - 0.24
d/B ratios	2.909 - 5.33	3, 6
Acoustic Boundary Conditions	Closed-Closed	Closed-Open
1L mode (Hz)	161.18	80.59
2L mode (Hz)	322.35	241.76



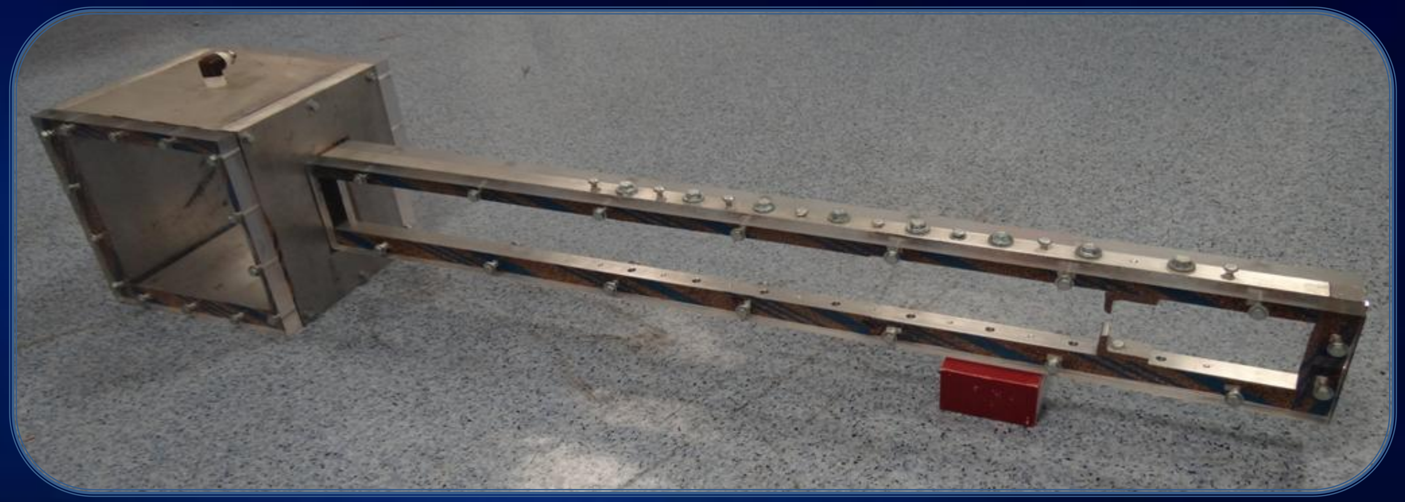
Side view of test section inhibitors



Previous schlieren imaging setup

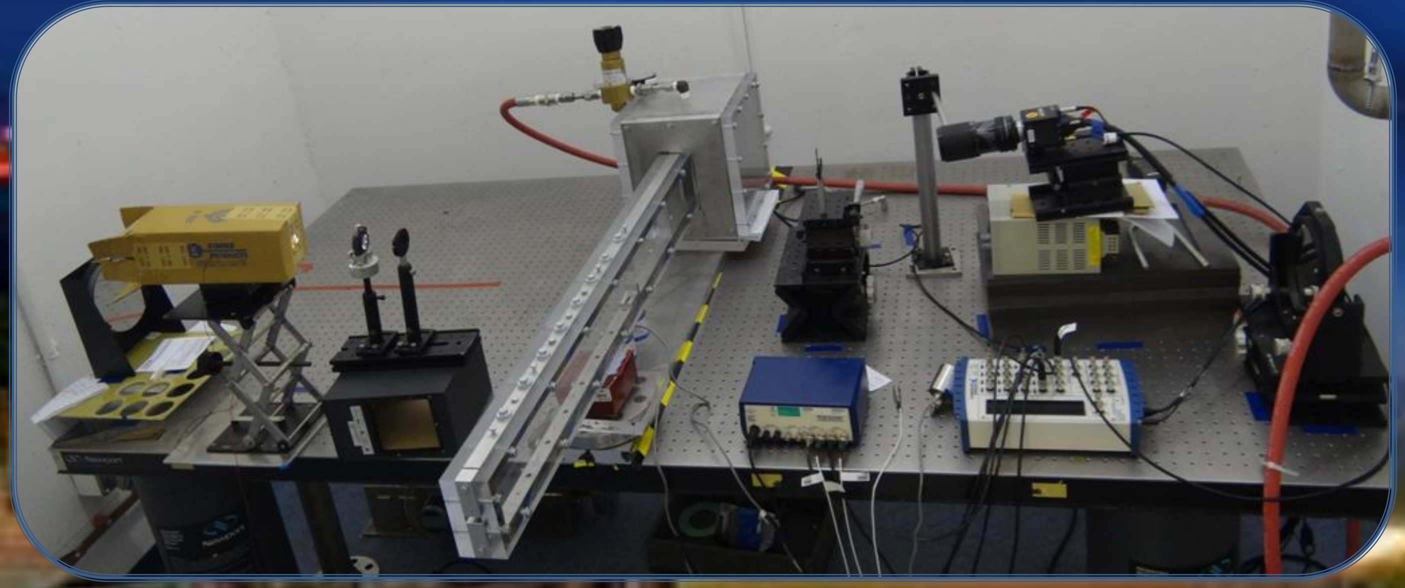
Chamber Design Improvements

- Larger settling chamber for better acoustic isolation
- Introduce honeycomb for flow straightening
- Redesigned inhibitors
  - Unlimited d/B range
  - Pairs of various shape and size
- Horizontal nozzle exit to match flow profile

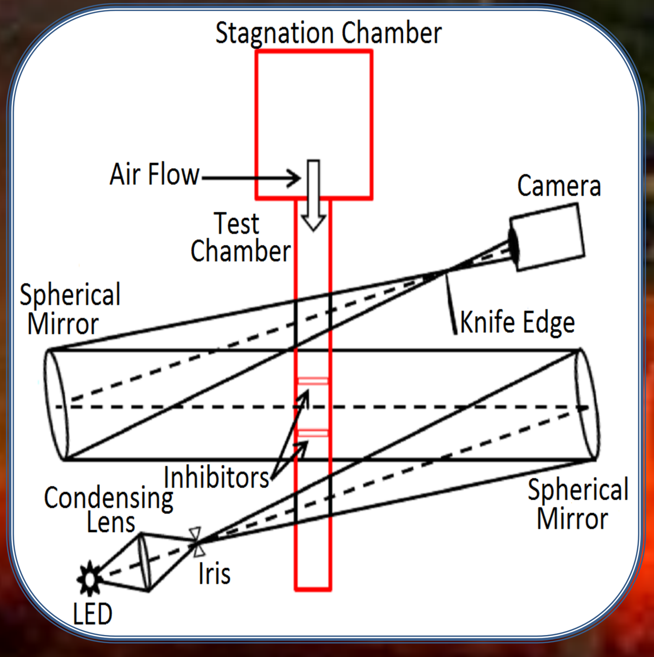

Test chamber with one inhibitor pair - air moves from the stagnation chamber on the left, through the test section, and out the nozzle on the far right

Schlieren System Changes

- New high power LED used for light source
- 2 matching spherical mirrors provide less distortion
- Both light source and camera raised vertically to see over test chamber


Schlieren system setup with light source on the left and camera on the right

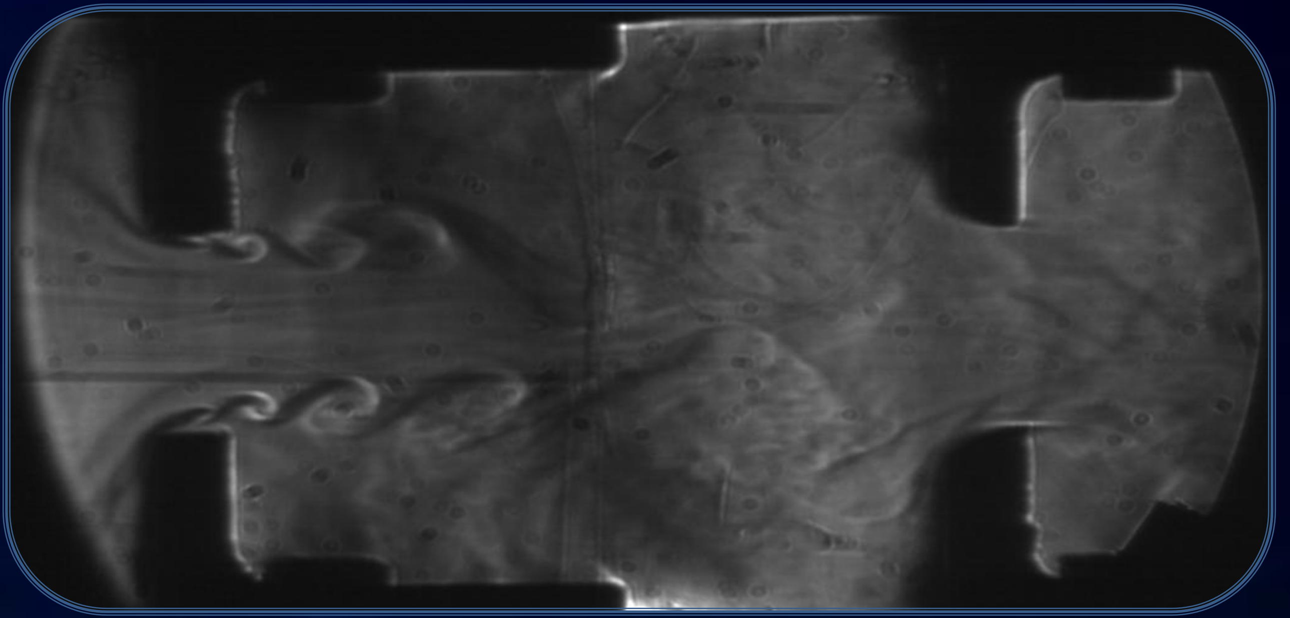

Schlieren image of flame plume from lighter shortly after ignition

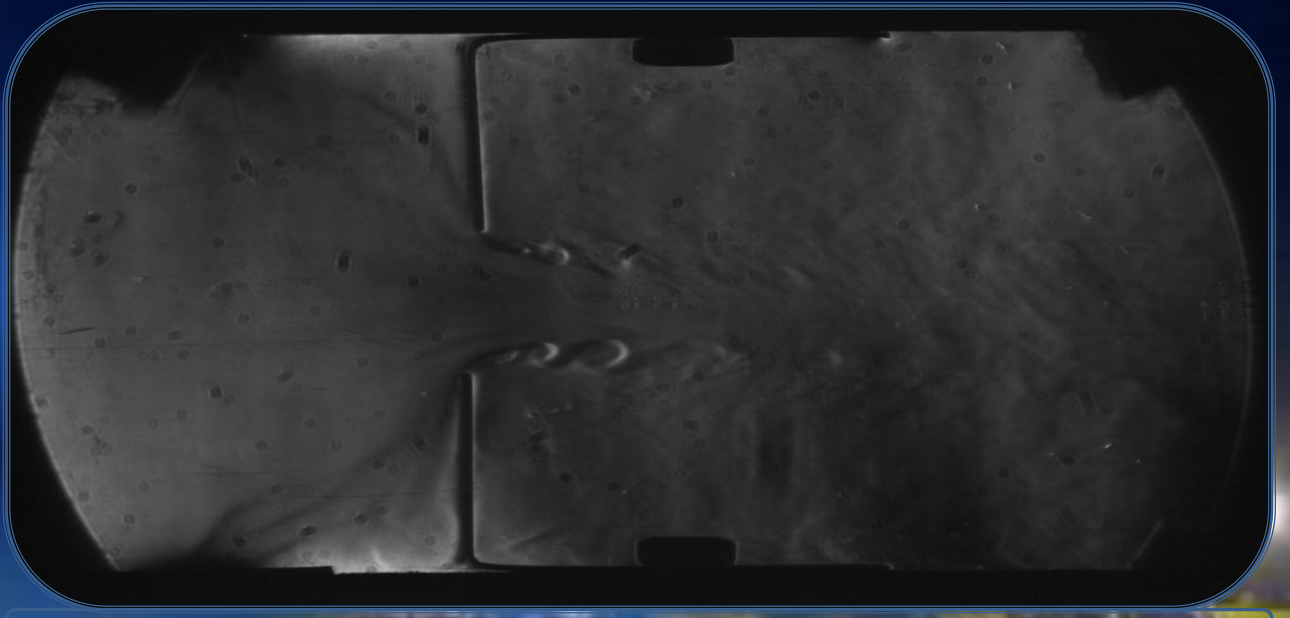


New layout of schlieren system - light now passes above the test section

Results

- Only transient vortices observed
- Inhibitor edge rounding weakened vortices
- Thinner inhibitors have smaller vortices
- Nozzle area too large to choke flow
  - Smaller throat provides weaker but longer lasting transient vortices
- Modified Schlieren provides acceptable images


Schlieren image of vortices being shed from 1/4" inhibitors


Schlieren image of 1/16" inhibitors shedding vortices

Concepts for Future Investigation

- Flexible rubber inhibitors
- Variable throat nozzle
- Contoured nozzle shape
- Smoke streakline visualization

Technological Impact

- Better understanding of SRM resonance and flow induced vibrations
- Improved design of inhibitors, casings, and grains to avoid induced oscillations
- Validation of CFD modeling
- Safer and more reliable SRMs

Propulsion Systems Department — Engineered to Excel–Driven to Explore

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